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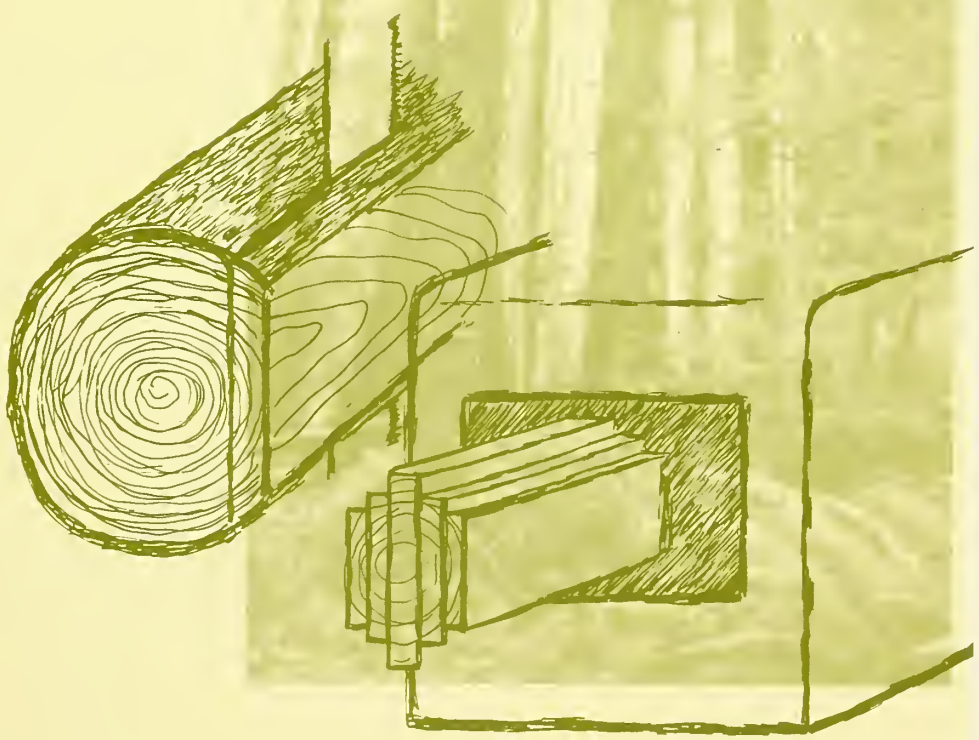
LUMBER RECOVERY from GRAND FIR THINNINGS at a BANDMILL and CHIPPING CANTER



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Abstract

Trees cut in thinning of a grand fir stand were processed in a bandmill and a Chip-N-Saw facility. Lumber grades produced were similar at each mill. The Chip-N-Saw as operated here produced considerably less lumber and sawdust and substantially more chips per unit of log measure.

Keywords: Lumber recovery studies, grand fir, thinnings.

Summary and Conclusions

Grand fir thinnings processed at a bandmill and a Chip-N-Saw produced 89 and 83 percent, respectively, of total lumber in Standard and Better grades.

The bandmill produced more lumber, more sawdust, and considerably less chips than the Chip-N-Saw per unit of log volume.

Overruns, based on uniform Bureau scaling methods and volumes, and surfaced dry lumber were 63 percent for the bandmill and 29 percent for the Chip-N-Saw. Of this 34-percent difference, 27 percent can be attributed to mill operations and 7 percent to log diameter distribution.

The difference in overruns between the mills has little relation to lumber sizes. Of the 27 percent attributed to differences in the milling process, not more than 3 percent can be explained in terms of volumes of 1-inch boards. Apparently the operation of the mills influenced the recovery of 2-inch dimension items also.

The proportion of lumber grades and items was quite similar at both mills. Differences probably resulted from drying and planing practice. The rough green lumber grades were slightly higher at the Chip-N-Saw than at the bandmill, but grades were slightly lower in the surfaced dry condition.

Log cubic volume proved a much better predictor of lumber recovery than Scribner scale. At either mill, the coefficients of variation were as follows:

	Bandmill	Chip-N-Saw
	Percent	
Recovery ratio (board-foot lumber tally/net log scale--Scribner)	27.6	35.5
Lumber recovery factor (board-foot lumber tally/log cubic volume)	20.7	21.1

At the time the study logs were processed, the prices per thousand board feet of lumber were approximately: Standard and Better--$75, Utility--$40, and Economy--$20. The chip price was approximately $18 per ovendry ton. The relatively low lumber price and stable chip price in effect at the time may have affected the products produced at the Chip-N-Saw.

Summary of Recovery by Mill[1/]

Characteristic	Bandmill	Chip-N-Saw
Mean log scaling diameter, inches	6.9	6.5
Diameter range, inches	4-14	4-12
Scaling defect, percent	3	4
Standard & Better lumber, percent	89	83
Utility and No. 3 lumber, percent	9	14
Economy lumber, percent	2	3
Percent overrun (surfaced dry)	63 (59)	29 (32)
Percent log cubic volume in rough green lumber	54.4 (53.6)	48.1 (49.9)
Total chip recovery, dry tons	22.40	[2/] 28.16
Dry tons of chips/M net log scale	.91	1.38
Dry tons of chips/M cubic feet	4.07	6.00

[1/] Figures in parentheses are developed from regression and covariance analysis to eliminate the differences due to unequal log diameter distributions at the two mills.

[2/] Does not include chips developed in board trimming or resawing of less than 1 dry ton.

Introduction

Commercial thinning sales are producing an increasing part of the total timber harvest in the Pacific Northwest. Grand fir *Abies grandis* (Dougl.) Lindl.) is one of the most common of the species that grow in association with either Douglas-fir or ponderosa pine. As lumber, it is usually combined with white, noble, and Pacific silver firs and western hemlock and marketed as hem-fir.

In 1970 the Forest Service and the Bureau of Land Management cooperated with the forest products industry to conduct a lumber recovery study on logs from a commercial thinning timber sale. They were processed in April 1970 through a bandmill and a 12-inch capacity Chip-N-Saw with a 4-inch center cant and a double arbor circular saw for cant breakdown.[3/] The details of study methods and mill equipment are in the Study Procedures section at the end of this paper.

The information on lumber and chip recovery will be useful to mill operators and timber managers in predicting product yields from similar stands, and evaluating different production methods.

Results

The study results are presented in a series of tables and in figures designed to illustrate the relative differences in recovery between the two mills.

The tables are arranged to allow the user to apply product prices. The lumber from the two mills was quite similar in grade and item. Only the ratio of chips to lumber and fluctuations in chip and lumber prices would result in any pronounced variation in product values.

Example, using figures from the summary and prices of $140 per thousand board feet for Standard and Better, $110 for Utility, $60 for Economy, and $25 per ton of chips:

3/ Mention of companies or products does not constitute endorsement by the U.S. Department of Agriculture.

	Bandmill			Chip-N-Saw		
	Percent	Price	Value	Percent	Price	Value
Standard & Better	89	x$140	= $124.60	83	x$140	= $116.20
Utility	9	x 110	= 9.90	14	x 110	= 15.40
Economy	2	x 60	= 1.20	3	x 60	= 1.80
Value/M lumber tally			$135.70			$133.40
Lumber value/M net log scale	[4/] 159	x 135.70	= $215.76	[4/] 132	x 133.40	= $176.09
	Tons/M	Price	Value	Tons/M	Price	Value
Chip value/M net log scale	0.91	x $25	= $22.75	1.38	x $25	= $34.50
Total value/M net log scale			$238.51			$210.59

RECOVERY RATIO (OVERRUN)

The most commonly used recovery ratio is board feet lumber tally per board foot of net log scale expressed as a percent. It is equal to "overrun" plus 100 percent. The recovery ratio of surfaced dry lumber averaged 163 percent for bandmill and 129 percent for the Chip-N-Saw (table 1). Adjustment[5/] for different log diameter distributions brings the recoveries to 159 percent for the bandmill and 132 percent for the Chip-N-Saw. The largest differences were in the 6- and 7-inch scaling diameter logs. We believe this was caused by the Chip-N-Saw operator's inability to estimate the log diameter and select the proper machine setting for small logs. His view of logs was obscured by the enclosed infeed chain. Figure 1 shows the general relationship of the recovery ratios at the two mills.

The low recovery reported at the Chip-N-Saw, particularly on 6- and 7-inch logs, led the cooperator to install log diameter sensing equipment. Studies completed since then on Chip-N-Saws with diameter sensors show considerably higher overruns with logs of the same diameter range.

[4/] 100 + overrun.

[5/] See footnote 1.

Table 1.--Lumber recovery per unit net log scale by mill for surfaced dry lumber

Scaling diameter (inches)	Scribner		Lumber tally	Recovery ratio
	Gross	Net		
	Board feet			*Percent*
Bandmill:				
4	690	690	1,333	193
5	4,590	4,590	6,941	151
6	2,580	2,480	3,671	148
7	3,480	3,400	5,388	158
8	4,010	3,850	6,619	172
9	3,840	3,680	6,472	176
10	2,910	2,830	4,417	156
11	1,040	1,030	1,664	162
12	1,230	1,180	2,075	176
13	650	640	1,014	158
14	230	190	301	158
All logs	25,250	24,510	39,895	163
Chip-N-Saw:				
4	100	100	187	187
5	5,150	5,070	6,671	132
6	4,690	4,470	4,918	110
7	3,100	2,920	3,472	119
8	3,230	3,130	4,282	137
9	1,750	1,660	2,407	145
10	2,300	2,230	3,125	140
11	420	390	567	145
12	460	460	655	142
All logs	21,200	20,430	26,284	129

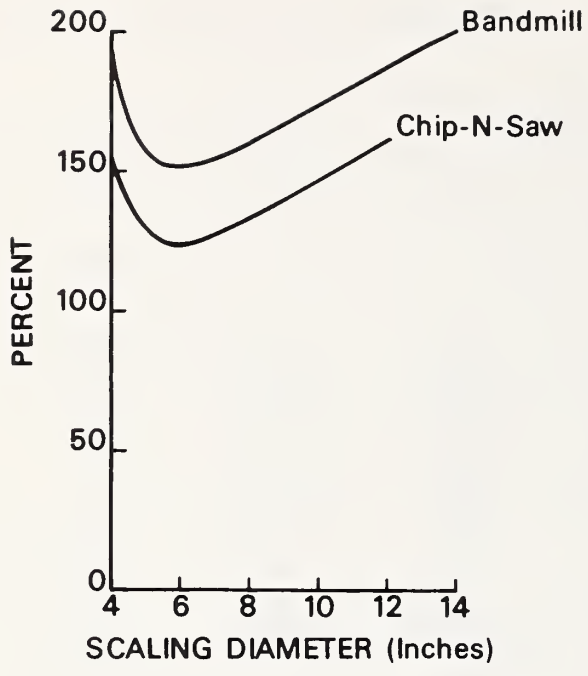

Figure 1.--Recovery ratio, board feet of lumber tally (surfaced dry) per board foot of net log scale.

LUMBER RECOVERY FACTOR

Lumber recovery factor is board feet of rough green lumber tally per cubic foot of gross log volume (table 2). The recovery factor for the bandmill averaged 7.51 board feet per cubic foot of log, while the recovery factor at the Chip-N-Saw was 5.92 board feet. When the diameters were adjusted to equalize scaling diameter distributions, the ratios were 7.29 at the bandmill and 6.22 at the Chip-N-Saw. Figure 2 shows the general trend of recovery factors for the two systems. As with recovery ratios, the big differences were in the 6- and 7-inch logs.

Figure 2.--Recovery factors, board feet of lumber (rough green) per cubic foot of log volume.

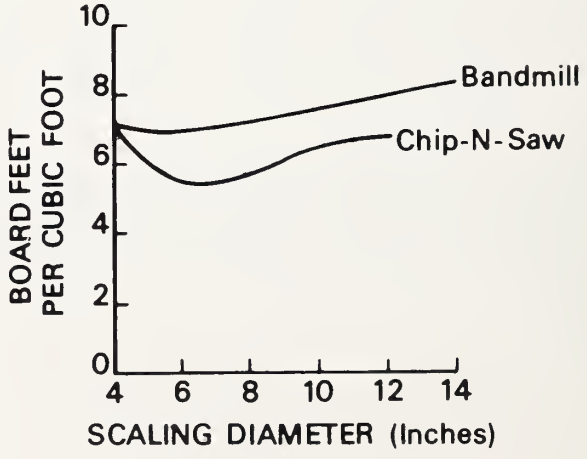

Table 2.--Recovery of rough green lumber, sawdust, and chippable volume

Scaling diameter (inches)	Total rough green lumber recovery	Gross volume of logs	Recovery factor	Lumber volume		Sawdust volume		Chippable volume	
	Board feet	*Cubic feet*		*Cubic feet*	*Percent[1/]*	*Cubic feet*	*Percent[1/]*	*Cubic feet*	*Percent[1/]*
Bandmill:									
4	1,387	183.93	*7.54*	103.89	*56.5*	22.49	*12.2*	57.55	*31.3*
5	7,189	1,017.00	*7.07*	535.75	*52.7*	115.98	*11.4*	365.27	*35.9*
6	3,807	544.07	*7.00*	279.84	*51.4*	59.46	*10.9*	204.77	*37.6*
7	5,591	721.47	*7.75*	405.46	*56.2*	83.94	*11.6*	232.07	*32.2*
8	6,865	938.77	*7.31*	495.74	*52.8*	100.48	*10.7*	342.55	*36.5*
9	6,676	858.83	*7.77*	487.43	*56.8*	95.99	*11.2*	275.41	*32.1*
10	4,562	577.18	*7.90*	335.51	*58.1*	64.14	*11.1*	177.53	*30.8*
11	1,723	231.16	*7.45*	126.05	*54.5*	23.33	*10.1*	81.78	*35.4*
12	2,140	259.01	*8.26*	150.14	*58.0*	27.79	*10.7*	81.08	*31.3*
13	1,051	126.60	*8.30*	74.82	*59.1*	13.70	*10.8*	38.08	*30.1*
14	309	42.06	*7.35*	22.74	*54.1*	4.15	*9.9*	15.17	*36.1*
All logs	41,300	5,542.14	*7.51*	2,994.63	*54.9*	611.45	*11.1*	1,871.26	*34.0*
Chip-N-Saw:									
4	195	*6.09*	32.01	15.55	*48.6*	1.68	*5.2*	14.78	*46.2*
5	7,035	*6.27*	1,121.48	561.59	*50.1*	62.01	*5.5*	497.88	*44.4*
6	5,207	*5.94*	875.84	417.95	*47.7*	45.88	*5.2*	412.01	*47.0*
7	3,673	*4.30*	854.83	297.21	*34.8*	33.32	*3.9*	524.30	*61.3*
8	4,533	*6.26*	754.35	368.79	*48.9*	39.42	*5.4*	346.14	*45.9*
9	2,546	*6.57*	387.37	207.68	*53.6*	20.37	*5.3*	159.32	*41.1*
10	3,327	*7.01*	474.73	271.87	*57.3*	26.21	*5.5*	176.65	*37.2*
11	591	*6.98*	84.66	48.41	*57.2*	4.70	*5.6*	31.55	*37.3*
12	697	*6.51*	107.06	56.68	*52.9*	5.38	*5.0*	45.00	*42.0*
All logs	27,804	*5.93*	4,692.33	2,245.73	*47.9*	238.97	*5.1*	2,207.63	*47.0*

[1/] Percent of log volume.

CUBIC RECOVERY PERCENT

The cubic recovery of actual rough green lumber and the calculated wood volume converted to sawdust and chippable volumes are listed in table 2 by scaling diameter and for all logs. Figure 3 shows the percent of log volume in products and the individual relationships to diameter. Adjusted to eliminate differences due to scaling diameter distributions, the recovery percents are as follows:

	Bandmill	Chip-N-Saw	Difference
		Percent	
Surfaced dry lumber	42.9	36.5	6.4
Shrinkage, planer shavings, and trim	10.7	13.4	2.7
Rough green lumber	53.6	49.9	3.7
Sawdust	11.3	5.4	5.9
Chippable volume	35.1	44.7	9.6

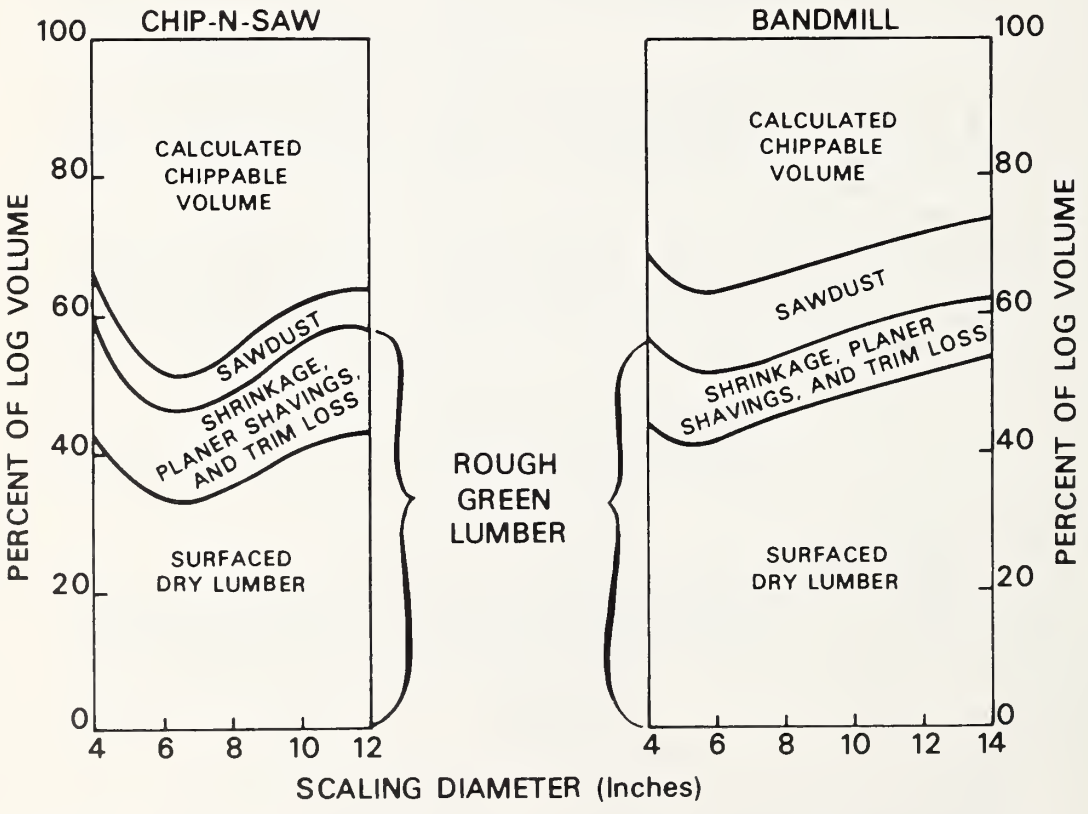

Figure 3.--Cumulative percentages of lumber, sawdust, and chippable volume.

The lumber processed at the Chip-N-Saw lost 2.7 percent more of the log cubic volume from rough green to surfaced dry tally than the bandmill. Of this loss, 2.6 percent can be attributed to larger rough green dimensions of the boards from the Chip-N-Saw, the other 0.1 percent being due to planer trimming. The Chip-N-Saw was apparently producing larger rough green lumber than necessary for finished sizes. The 1-inch green lumber at both mills was the same thickness. The net thickness of the 2-inch green lumber at the Chip-N-Saw was 1-29/32 inch, while the 2-inch green lumber at the bandmill was 1-24/32 inch thick. The widths were similar at both mills. The above tabulation shows that more of difference in chippable volume comes from differences in sawdust volume than differences in rough green lumber volume.

CHIP RECOVERY

The calculated chippable volume is the portion of total log cubic volume available for chipping, not actual chip volume recovery.

The calculated volume available for chipping was 1,871.26 cubic feet at the bandmill and 2,207.63 cubic feet at the Chip-N-Saw. The dry chips recorded on the study shipment invoices were 22.40 tons at the bandmill and 28.16 tons at the Chip-N-Saw.

The calculated chippable volume converts to 23.9 pounds per cubic foot for the bandmill and 25.5 pounds per cubic foot for the Chip-N-Saw.

The generally accepted weight for grand fir is 23 pounds per cubic foot[6/] based on green volume and ovendry weight. With allowance for screening loss and some chippable material hogged at the bandmill, the actual chippable volume was considerably higher than the calculated chippable volume. This is due in part to using nominal rather than actual log lengths but primarily to dropping fractional inches in scaling by Scaling Bureau rules.[7/]

6/ USDA Forest Service, Forest Products Laboratory. Wood Handbook No. 72, 527 p. U.S. Government Printing Office, Washington, D.C., 1955.

7/ David Bruce and Donald J. DeMars. Effect on diameter estimates of rounding rules in scaling. USDA Forest Service Research Note PNW-226, 8 p. Pacific Northwest Forest and Range Experiment Station, Portland, Oreg., 1974.

LUMBER GRADE RECOVERY

The recoveries by lumber grade are similar to other studies[8/] for small sound logs. The lumber recovery by grade and item is listed in table 3. The comparative percents by mill for surfaced dry lumber are as follows:

	Standard & Better	Utility	Economy
Bandmill	89	9	2
Chip-N-Saw	83	14	3

Any difference in lumber grades appears due to either grading or dry kiln and planing differences. A higher percentage of rough green Standard and Better was produced by the Chip-N-Saw than by the bandmill.

Table 3.--Percent of total production by grade and dimension by mill

Scaling dimension (inches)	Select structural	Construction no. 1	Standard no. 2	Utility and no. 3	Economy	Total
			Percent			
Bandmill:						
1 x 4	2.71	3.41	1.74	0.79	0.09	8.74
1 x 6	.16	.22	.14	.06	.01	.58
2 x 4	7.42	9.85	5.10	2.32	.41	25.09
2 x 6	10.10	14.48	7.80	3.67	.62	36.67
2 x 8	6.35	8.28	4.14	1.82	.32	20.92
2 x 10 and wider	2.59	3.21	1.53	.58	.08	8.00
Total	29.32	39.46	20.45	9.24	1.53	1/ 100.00
Chip-N-Saw:						
1 x 4	2.20	2.98	1.15	.84	.17	7.34
1 x 6	.10	.38	.20	.41	.14	1.24
2 x 4	6.74	15.74	6.21	4.60	1.05	34.35
2 x 6	7.06	14.43	5.71	4.97	1.24	33.42
2 x 8	3.28	8.16	3.28	2.47	.51	17.70
2 x 10 and wider	.99	3.12	1.18	.60	.06	5.95
Total	20.39	44.81	17.74	13.89	3.17	1/ 100.00

1/ Cross totals may not add due to rounding.

8/ J. Dobie and C. F. McBride. Lumber recovery from second-growth Douglas-fir in British Columbia. Forest Products Journal 14: 55-60. 1964. Also see Thomas D. Fahey and Donald C. Martin. Lumber recovery from second-growth Douglas-fir. USDA Forest Service Research Paper PNW-177, 20 p. Pacific Northwest Forest and Range Experiment Station, Portland, Oreg., 1974.

One-inch lumber comprised 9.3 and 8.6 percent of the total lumber volume at the bandmill and Chip-N-Saw, respectively. This accounted for 15.2 and 11.1 percent of the overrun. Therefore, no more than 3.1 percent of the difference in study overrun can be accounted for by differences in recovery of 1-inch lumber.

Lumber grade did not vary appreciably by log scaling diameter (table 4). This was also true in the rough green lumber grades before conversion to surfaced dry grades.

Table 4.--Lumber grade recovery as a percent of lumber tally volume and number of logs by diameter class and mill

Scaling diameter (inches)	Number of logs	Select structural	Construction no. 1	Standard no. 2	Utility and no. 3	Economy
			Percent			
Bandmill:						
4	38	29.03	39.16	20.86	9.45	1.50
5	157	28.92	39.29	20.54	9.72	1.53
6	57	29.47	38.95	20.22	9.64	1.72
7	64	25.98	39.07	22.10	10.82	2.03
8	61	29.11	39.70	20.56	9.14	1.49
9	41	29.96	39.97	20.10	8.56	1.41
10	24	30.47	39.26	19.76	8.90	1.61
11	7	29.15	39.12	20.79	9.44	1.50
12	8	32.24	40.34	19.33	7.37	.72
13	4	33.53	39.45	18.34	7.50	1.18
14	1	37.87	40.53	16.61	4.65	.34
All logs	462	29.32	39.46	20.44	9.25	1.53
Chip-N-Saw:						
4	5	11.76	48.66	19.79	16.05	3.74
5	171	19.50	44.36	18.40	14.35	3.39
6	92	20.29	46.18	17.67	13.03	2.83
7	56	20.82	45.48	17.02	13.59	3.09
8	48	22.09	44.23	17.56	13.17	2.95
9	20	19.24	42.46	17.95	16.33	4.02
10	18	21.22	44.70	16.99	13.99	3.10
11	4	21.16	48.50	16.23	11.29	2.82
12	3	18.63	44.43	20.14	14.20	2.60
All logs	419	20.39	44.81	17.74	13.89	3.17

Study Procedures

TIMBER SAMPLE AREAS

The study trees were taken from two timber sales in one 65-year-old stand on site class IV in the Hood River District of the Mount Hood National Forest in Oregon. The stand basal area per acre was 110 square feet of grand fir and 30 square feet of Douglas-fir. Basal area cut was 35 square feet of grand fir and 1 square foot of Douglas-fir per acre. None of the Douglas-fir cut was processed during the study.

Trees were selected by the District timber sale crew to salvage existing or anticipated mortality but primarily to improve growing conditions and spacing for the residual trees.

Equipment at the bandmill did not limit log size; therefore some larger trees were included than in the Chip-N-Saw sample (table 5).

LOG SCALING AND GRADING

The woods-length logs were scaled and graded in the millyard by a U.S. Forest Service check scaler. Scaling was according to uniform Bureau rules for west side,[9/] with logs up to 40 feet in length being scaled as one piece. Logs were graded according to the rules for hemlock, silver, and white fir when grading logs in the standing tree.[10/] Defects not visible nor indicated on the log surface were not considered in grading.

CUBIC MEASUREMENTS

Cubic volume computations are based on the scaling length and end diameter measurements of the woods-length logs. Butt log large end diameters are measured on a projected conic section and exclude stump flare. Log cubic volume is computed by the formula

$$V = \frac{\pi(D_s^2 + D_s D_1 + D_1^2) \times L}{3 \times 4 \times 144}$$

where $\pi = 3.1416$

D_s = small end diameter in inches

D_1 = large end diameter in inches

L = nominal length in feet

No deductions were made from log gross cubic volume.

[9/] Official Log Scaling and Grading Rules (July 1, 1972, revision) used by log scaling and grading bureaus: Columbia River--Eugene, Oregon; Puget Sound--Tacoma, Washington; Gray's Harbor--Hoquiam, Washington; Southern Oregon--Roseburg, Oregon; and Northern California--Arcata, California. Copies may be obtained from any of these Bureaus.

[10/] Log grade descriptions for hemlock, silver, and white fir. Form R-6-2440-19D (March 1963). Unpublished material on file at U.S. Forest Service, Region 6, Portland, Oreg.

Table 5.--Log input and number of logs by diameter class as a percent of net Scribner and gross cubic volumes

Scaling diameter (inches)	Bandmill			Chip-N-Saw		
	Number of logs	Scribner	Cubic	Number of logs	Scribner	Cubic
		- - - *Percent* - - -			- - - *Percent* - - -	
4	38	2.82	3.34	5	0.49	0.68
5	157	18.52	18.49	171	24.82	23.90
6	57	10.12	9.89	92	21.88	18.66
7	64	13.87	13.12	56	14.29	18.22
8	61	15.71	17.07	48	15.32	16.08
9	41	15.01	15.62	20	8.13	8.26
10	24	11.55	10.49	18	10.91	10.12
11	7	4.20	4.20	4	1.91	1.80
12	8	4.81	4.71	3	2.25	2.28
13	4	2.61	2.30	0	--	--
14	1	.78	.77	0	--	--
Total	462	100.00	100.00	417	100.00	100.00

Cubic lumber volumes in table 2 are based on sample measurements of actual rough green lumber width and thickness and nominal lumber lengths. Cubic volume of wood converted to sawdust is based on a calculation using board surface area and an average kerf for the mill. The actual kerf on the Chip-N-Saw was adjusted to compensate for the amount of board surface which was "profile" chipped and for which no kerf developed. Chippable volumes are computed by subtracting lumber and sawdust cubic volume from log cubic volume.

PROCESSING AND INDIVIDUAL MILL SETUP

In the woods, each log was given a number identifying the tree and the log position in the tree. At the mill, lumber was identified with the mill and scaling length log and tree.

The bandmill equipment included a debarker, band headrig for primary breakdown, reciprocating gangsaw, two edgers, a vertical band resaw, and a gang trimsaw. Rough green grading and tally were done on the green chain.

The Chip-N-Saw was part of a mill complex which included a bandmill. It had a separate barker; however, the trimsaw and edger were inside the main mill. Green grading and tallying were done on the chain from the Chip-N-Saw to the main mill. Pencil trim or rip[11] was also marked at this time.

LUMBER GRADING

All lumber was given a rough green grade[12] by an inspector from the West Coast Lumber Inspection Bureau or Pacific Lumber Inspection Bureau. At the Chip-N-Saw, pencil trim or rip was also designated by the grade inspector. Pencil trim or rip was used only when required to tally a board as a recognized lumber grade, not to upgrade boards.

LUMBER TALLY

Lumber was tallied in the rough green condition by Forest Service crews working immediately after the grader. Each board was tallied by width, thickness, length, grade, and the identification number of the log. Pencil trim and rip were deducted from the actual length and width as the boards were tallied.

Because most grand fir lumber is sold surfaced dry, it was necessary to convert the lumber recovery, by log, to a dry grade and volume. This was done by developing and applying conversion factors.

Development of these conversion factors required sorting the rough dry lumber by planing item within each rough green grade. After sorting, the lumber was planed. An Association inspector then regraded the surfaced dry stock. Actual trimming for upgrading occurred at this point. Forest Service crews made separate dry tallies for each green grade sort. These tallies showed the proportion of surfaced dry grades resulting from each green grade, including cull and trim loss. Applying these factors to the grade and volume of rough green lumber in each log placed the study on a surfaced dry basis.

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[11] Reduction in board length or width, marked by the grader, when edging or trimming was necessary.

[12] West Coast Lumber Inspection Bureau. Standard grading and dressing rules for Douglas-fir, West Coast hemlock, Sitka spruce, western redcedar lumber. No. 15, revised. Portland, Oreg., 1968.

CHIP RECOVERY

At the beginning of the study an empty chip bin was provided. All study chips were put in one shipment. The ovendry weight of the chips was determined by the chip purchaser. The total of ovendry tons for the study was determined from the purchaser's invoice. At the Chip-N-Saw all the pencil trim or rip was excluded from the green lumber tally. Since trimming and edging were done inside the main mill, all chippable material from log end trim as well as pencil trim and rip were lost from chip totals. This volume could not have exceeded 1 ovendry ton of chips.

DATA COMPILATION AND ANALYSIS

The data was edited and compiled using a computer program[13/] developed for compiling lumber recovery data.

Statistical analyses were run to test the relationship between cubic recovery ratios and factors by log diameters at both mills. Multiple linear regressions were run, and the curve form which best fit the data was selected on the basis of the lowest mean squared error term. The mathematical model which best fit the recovery data was as follows (D = log scaling diameter):

Bandmill: $\text{Ratio} = a + \frac{b}{D} + \frac{c}{D^2}$

Chip-N-Saw: $\text{Ratio} = a + bD + cD^2 + dD^3$

The Chip-N-Saw curves level or drop at the end because some of the larger logs were slightly larger than the machine had been designed to handle.

Because of different curve forms, the two mills cannot be compared directly. Both sets of data were compared by analysis of covariance on each of the curve forms. The conclusion from analysis of both forms was the same. The difference in slope of the lines was not significant, but the difference in the adjusted means was significant at the 1-percent probability level for either curve. By inference, there was a significant difference in the efficiency of the processes, which varied little by log scaling diameter.

Statistical inferences about the differences in recovery ratio ([lumber tally/net log scale] x 100) are based on the curve form

$$Y = a + \frac{b}{D} + \frac{c}{D^2}$$

because this was the best fit for both mills.

13/ John W. Henley and Jill M. Hoopes. An electronic computer program for calculating saw log lumber recovery and value. USDA Forest Service, 47 p. Pacific Northwest Forest and Range Experiment Station, Portland, Oreg., 1967.

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Within this overall mission, the Station conducts and stimulates research to facilitate and to accelerate progress toward the following goals:

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